DataRay Inc.

Camera Based 2-16 µm Beam Profiler

WinCamD™-FIR2-16-HR Manual Supplement *for Ver. 7.1H24N or higher*

Observe max irradiance limits (or pay for sensor replacement).

Carefully read this supplement ***twice*** before attempting to use the camera.

Camera shown ≈actual size

2.40 x 2.65 x 0.90" (x 1.10" with ND filter)
[61 x 67 x 22 mm]

Compact, Portable, Port-Powered, USB 2.0 *FIR* Beam Profiling for Windows 7, Vista & XP

Features

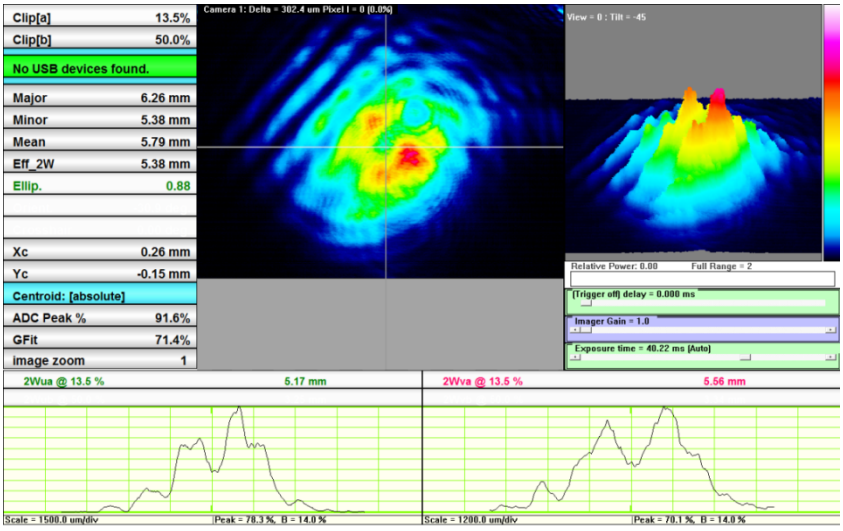
- ◊ **17 µm pixel pitch, 640 x 480 pixels**
- ◊ **12.24 x 8.16 mm Image Area**
- ◊ **Silicon microbolometer**
- ◊ **Port Powered USB 2.0**; flexible 3 m cable, *no power brick*
- ◊ **0.90" (24 mm) thin**
- ◊ **12-bit ADC**, 4 MB image buffer & on-board microprocessor
- ◊ **>100:1 Signal to rms noise** attainable
- ◊ **Imager Gain** range **16:1**
- ◊ **10:1 ND** absorbing screw-on filter provided for 2 -4 µm
- ◊ **No Chopper Required -** Measure Pulsed or CW Beams
- ◊ **Room Temperature** - no cooling/TE power required

Applications

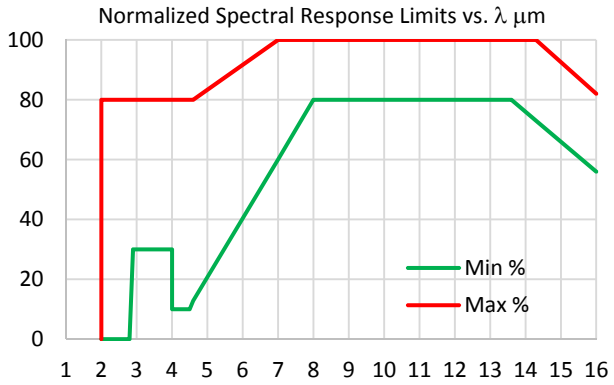
- ◊ MIR/FIR laser profiling
- ◊ Field servicing of MIR/FIR lasers and laser-based systems
- ◊ Optical assembly & instrument alignment
- ◊ Beam wander & logging

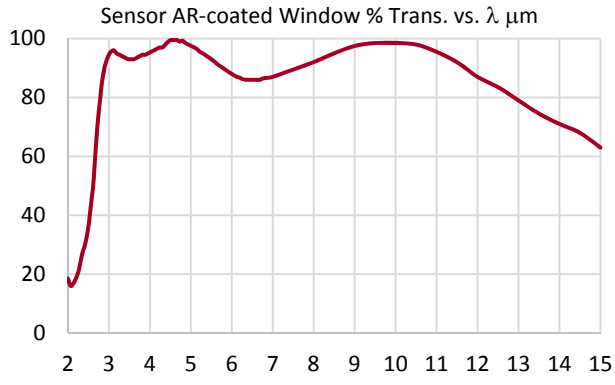
IMPORTANT

- ◊ <~1 mW/mm² (<~100 mW/cm²) saturation CW irradiance over wavelength range at imager gain =1. See curve on next page.
- ◊ **~10 mW/mm² (1 W/cm²) burn-in damage threshold**.
- ◊ Carefully measure your beam irradiance *before* exposing camera to beam.
- ◊ Minimize time that the camera spends in higher irradiance beams. Long-term over-exposure can increase dark current.



13 mW, λ≈ 3 µm laser image , Imager Gain =1

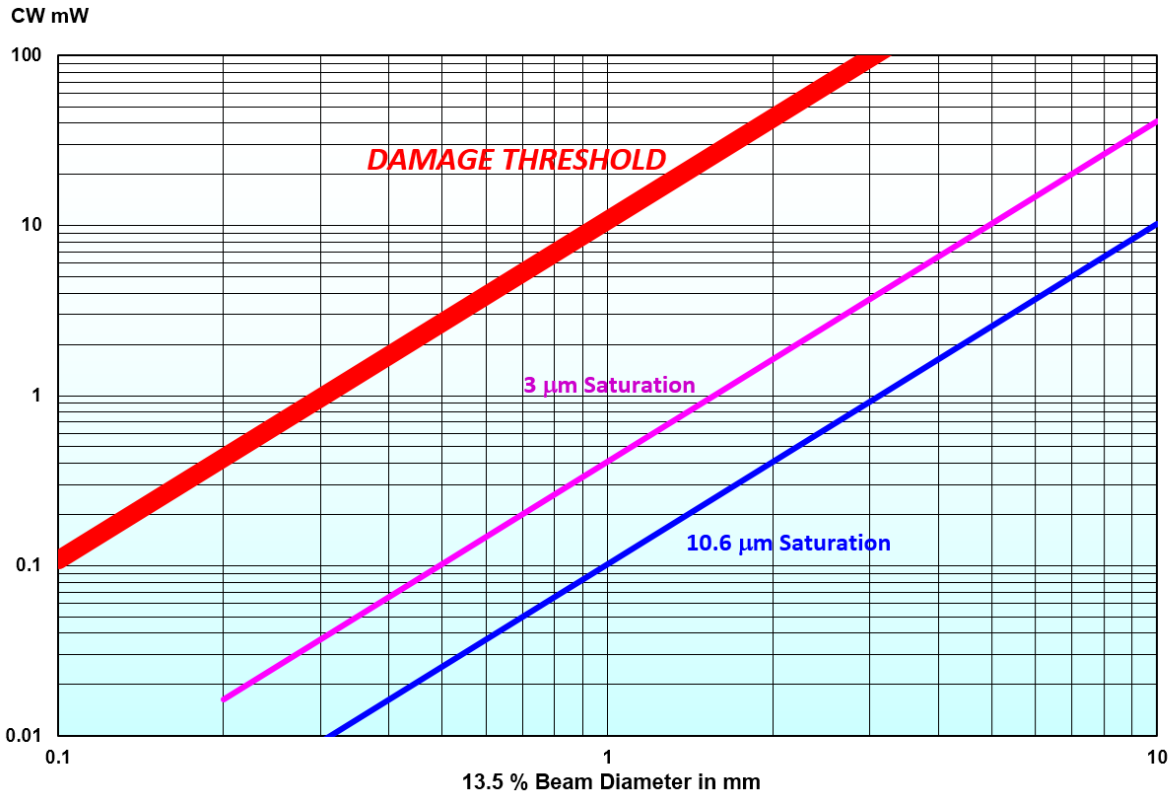




Very Expensive Sensor **Observe max irradiance limits (or pay for sensor replacement)**

Saturation Irradiance limits & Damage Thresholds

1) We cannot stress strongly enough that the maximum irradiance limits must be observed. To facilitate this we provide two graphs of ***APPROXIMATE*** maximum signal versus beam diameter at 3 & 10 µm. However, in our experience, many IR lasers beams have '**peaky**' profiles, rather than smooth Gaussian or top hat pixels. *Even on commercial lasers we have seen major profile variations of peak intensity and position with time - see burnt sensor image on page 4!*



Approximate Damage & Saturation Limits

Damage threshold limits are ***approximately*** 10 to 20 times higher than the Saturation power limits.

Minimum detectable signal level? What is the minimum irradiance for a useful SNR with the WinCamD-FIR2-16-HR? Based on measurements on the 2.94 µm laser, we get excellent SNR, around >50, at 13 mW on a 5.5 mm beam. This is a peak irradiance of around 100 mW/cm^2. A noise level of around 1 to 2 mW/cm^2.

At longer wavelengths the sensor responsivity should improve these numbers by a factor of 2 to 3, but we do not currently have specific measurements on this.

Using the slider, you can increase total gain + integration by a factor of around 16. This raises both signal and noise. You can use averaging and background subtraction, you may be able to see irradiance down below the 1 mW/cm^2 level, but only a measurement will prove whether or not this is the case.

NEP? NEP is a single element detector figure of merit. We do not quote NEP for these sensor arrays.

NETD? The NETD for the sensor used is nominally <50 mK @ f/1, 300K, 30Hz, LWIR under optimum conditions. We do not measure NETD for these cameras.

WinCamD-FIR2-16-HR Setup and Use. Software Ver. 7.1H24G or higher

*** Warning *** Using any type of uncooled far-IR camera is different from using a standard CCD camera:

2) Like older plasma televisions, but more so, far-IR bolometric cameras are susceptible to 'burn-in' damage because the damage threshold is close to the saturation threshold and to the working irradiance range. Slight damage ***may*** anneal out, but major burn-in is irreparable.

   DataRay keeps supplies a post calibration reference image with every -FIR camera, so that any subsequent damage is simply determined.

3) The range of offset and exposure adjustment is lower than CCD's, so more care must be taken.

4) ***Never start a measurement unless you know that peak beam irradiance is <0.5 mW/mm²***. (***<5 mW/cm²)*** i.e. you have a calibrated power meter and an estimate of your beam diameter. See Appendix A for some available meters and filters.

5) ***Cumulative*** *exposure at high irradiance May cause burn-in and permanently damage the detector.* We recommend the use of a shutter or some way to block the beam quickly and easily in order to limit burn-in/shading due to cumulative exposure. Even below saturation, at low **Imager gain** try to keep the time per session that the laser is on the imager to minutes, not ten's of minutes. We may relax this restriction in the future.

6) With the FIR2-16 camera, DataRay includes an ND2.0 (@546 nm) filter which is usefully ND ~1.0 at wavelengths below 4 µm. See Appendix A for the transmission curve.

Safety

7) **Sensor Safety**. **IMPORTANT**: You are ***totally*** responsible for the safety of the expensive sensor. If you damage the sensor the replacement charge is many $1,000's. See **Irradiance limits & Damage Thresholds** and **Operation**, below.
8) **Laser Safety**. *You are totally responsible for your own laser safety and for the safety of your colleagues*. Wear appropriate goggles. Use appropriate screens and door interlocks.

Installation

9) ***Before*** *attaching the camera* you must install the software, open and close it, in order to install the driver. Install the camera on the computer per the main User Manual. Leave the cap on the camera. Start the software. Study the WinCamD manual & this supplement.

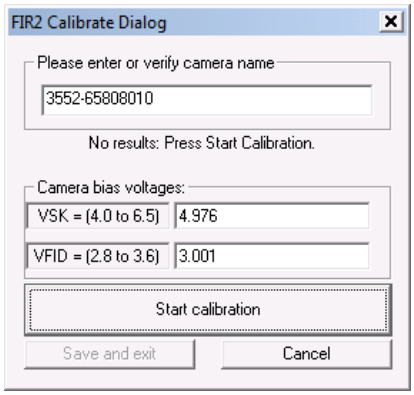
Calibration

10) The first time on any particular computer, a **Camera not calibrated** warning will appear.

    If a xxxx-yyyyyyyy**.uFir3_cal** file is provided on the CD, copy it to the **c:\Users\.....\Documents\DataRay** directory. Go to Step 14).

    If no **uFIR3.cal** file is provided, or if the software tells you to recalibrate go to Step 11).

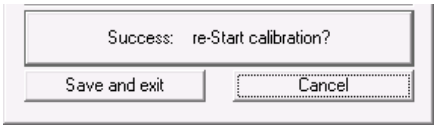
11) Place the screw-on cap on the camera (or lens cap on optional lens). Go for a break. Return in five minutes after the camera has warmed up. [*Required* before camera calibration. Recommended before normal use or if the camera temperature has changed.] In the **Setup** pull-down menu choose **Calibrate current Camera** to open the **FIR2 Calibrate Dialog**.



12) *Verify that the **Serial #**, **VSK** and **VFID** data in the calibrate dialog corresponds to the label on the top of the camera.* If not, enter the camera **SN** number from the label on top in the dialog. See label example right.

Enter the camera bias voltages **VSK** and **VFID** from the label on top of the camera. Press **Start Calibration**.

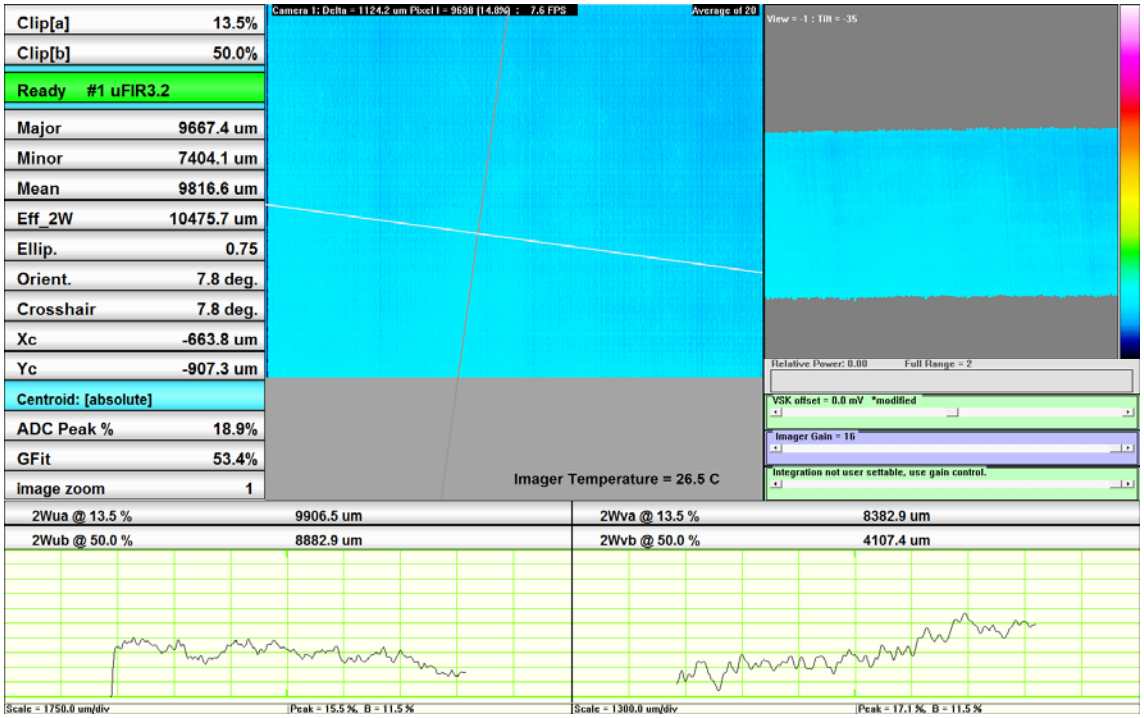
13) The calibration routine records the image offset maps and optimum VSK value at **Imager Gain** steps from 1.00 to 16. After several seconds you will see the line **Success: re-Start calibration?** appear in the dialog. Press **Save and exit.**



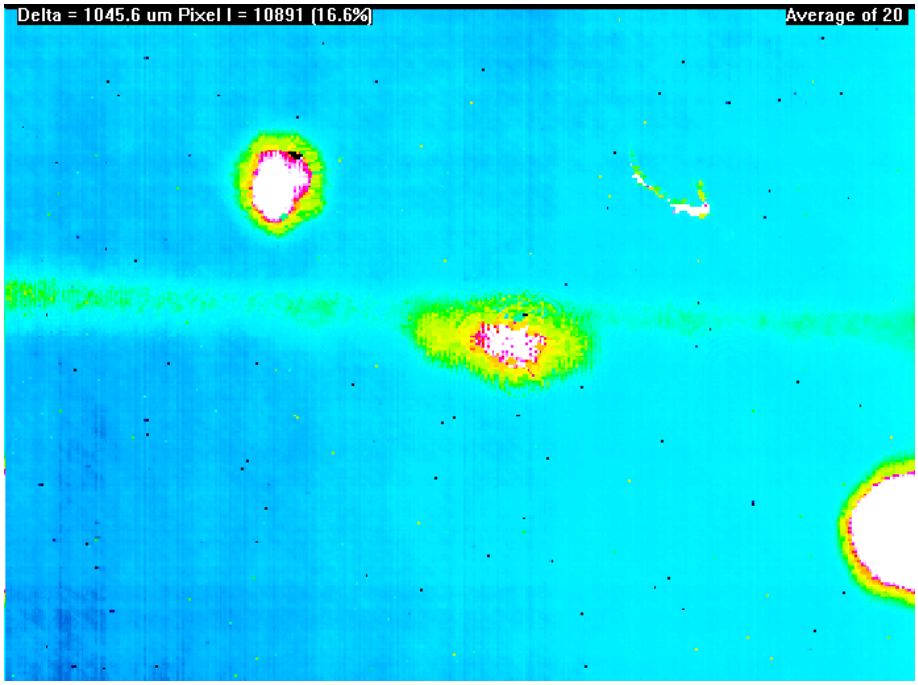
[The calibration file is saved in **c:\Users\.....\Documents\DataRay** directory as, this example, **3011-37422055.uFir3_cal**. If you move the camera to another PC, either redo the calibration or also move the file.]

Reference Image & Damage

14) After calibration, we take a Reference file at **Imager Gain = 16**, and **Average 20**. **IMPORTANT**: <u>In the event of any claims regarding imager damage, this is the definitive reference image</u>. A copy is kept with DataRay, and a copy accompanies the shipment. [The actual shade of blue will depend upon the ambient temperature and the most recent calibration.] *Note that there can be both dead and bright pixels, inevitable with microbolometers. See the Defective Pixels Specification in Appendix B.*

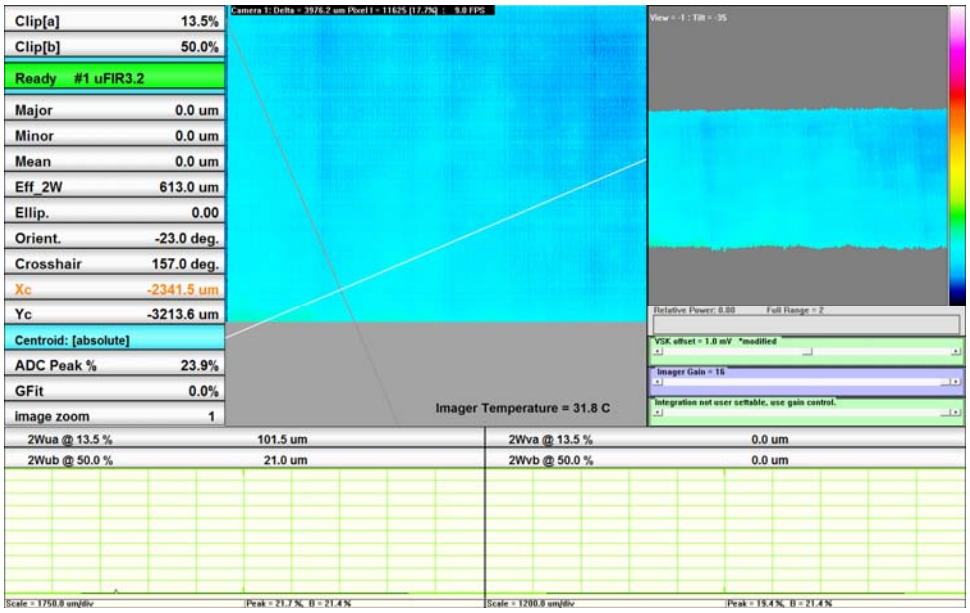


How to identify Damage. Below is an example of a sensor with white burn areas, plus a faint green left to right trail due to overexposure. ***Such user damage is not covered by warranty and is not repairable*****.** If your beam is small, you can continue to use the good areas of the sensor, but using **VSK** in **Auto** mode may be difficult. The good news is that the sensors (if still available) are replaceable at the factory. You do not need to purchase a new camera.



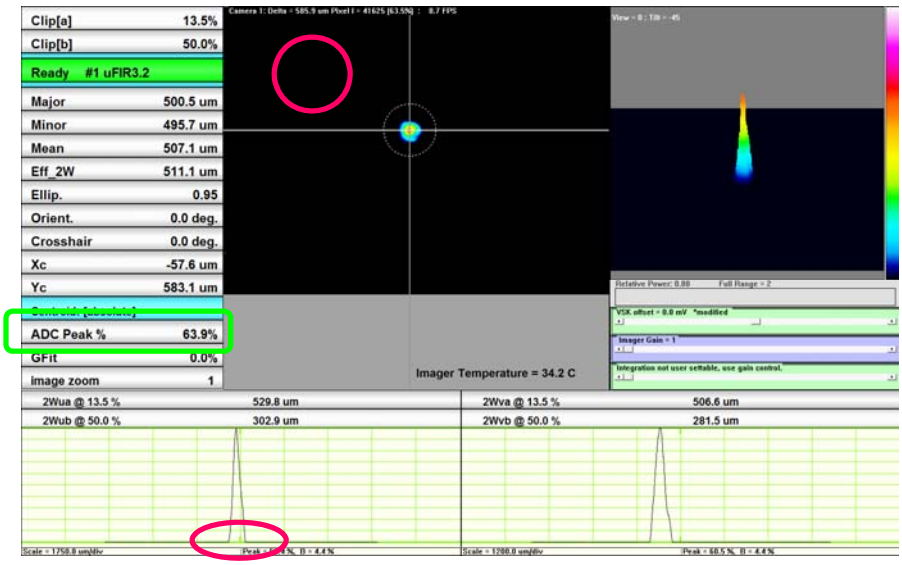
Operation

15) Press **G**o. You will see a screen similar to that shown below. The default settings put the **Imager Gain** to **16** and the **VSK offset Auto adjust** to off.



16) Measure your estimated beam irradiance. It must be ***<0.5 mW/mm²***. (***<50 mW/cm²***). Unscrew the plastic dust-cap. ***Peak irradiance of a Gaussian beam = 2.6 x power / (diam)². Real life beams may be more 'peaky' than this.***

17) *First time, carefully & iteratively 'walk' the beam in from the side while adjusting the* **Imager Gain**. As the beam saturates, stop walking the beam onto the sensor. As **ADC Peak %** approaches or exceeds **100%**, the screen values will turn **Orange** as a warning. As the beam saturates first use the middle slider to reduce the **Imager Gain**.

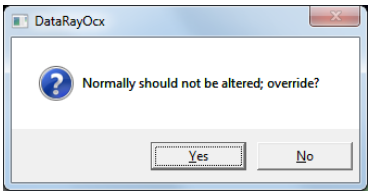


18) **Signal level too high?** If the **Imager Gain** is >1 use the middle slider to reduce the **Imager Gain**. *If the* ***Imager Gain*** *is fully to the left and you are still saturated, immediately block the beam remeasure the power and reduce the irradiance.* See Appendix A for samplers and attenuators.

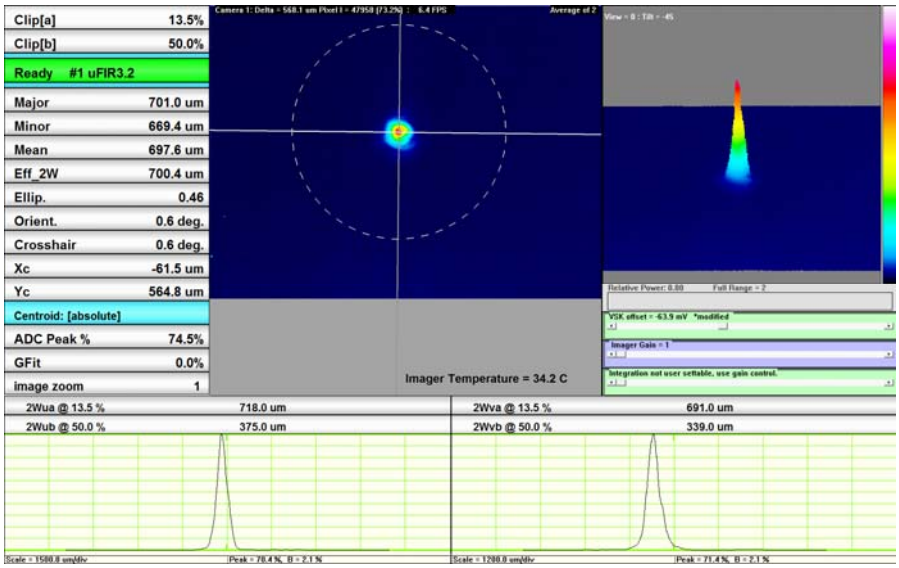
19) The Integration slider has no effect on performance/sensitivity. It is varied as a part of the Imager Gain.

20) **Signal level too low?** Increase **Imager Gain** at the expense of signal to noise ratio.

21) ***Examine the image***. Is the black in the 2D area very black, and/or the profiles look as if they are 'diving through zero' rather than smoothly blending into the baseline?



In the **Average** pull-down menu select **Average 2** (or higher). [A requirement to be removed in a subsequent software release.] Reduce the VSK value until these are no longer a problem. (If you see the message right, click **Yes**.)



22) **Readout in mm?** Want to read beam diameter in mm rather than μm. Go to **Setup** and choose **Numeric Display Modes ...** . Select **XXX.YY mm**.

23) **Smooth a large Beam or See Detail**? In the **Filter** pull-down menu select an **Area filter**. Area display filters improve visible SNR at the expense of resolution. E.g. the 3x3 pixels filter will improve SNR by a factor of ~3, but increases the effective pixel size from 35 x 35 μm to 105 x 105 μm. This is still ~50 resolution elements across a 5 mm beam.

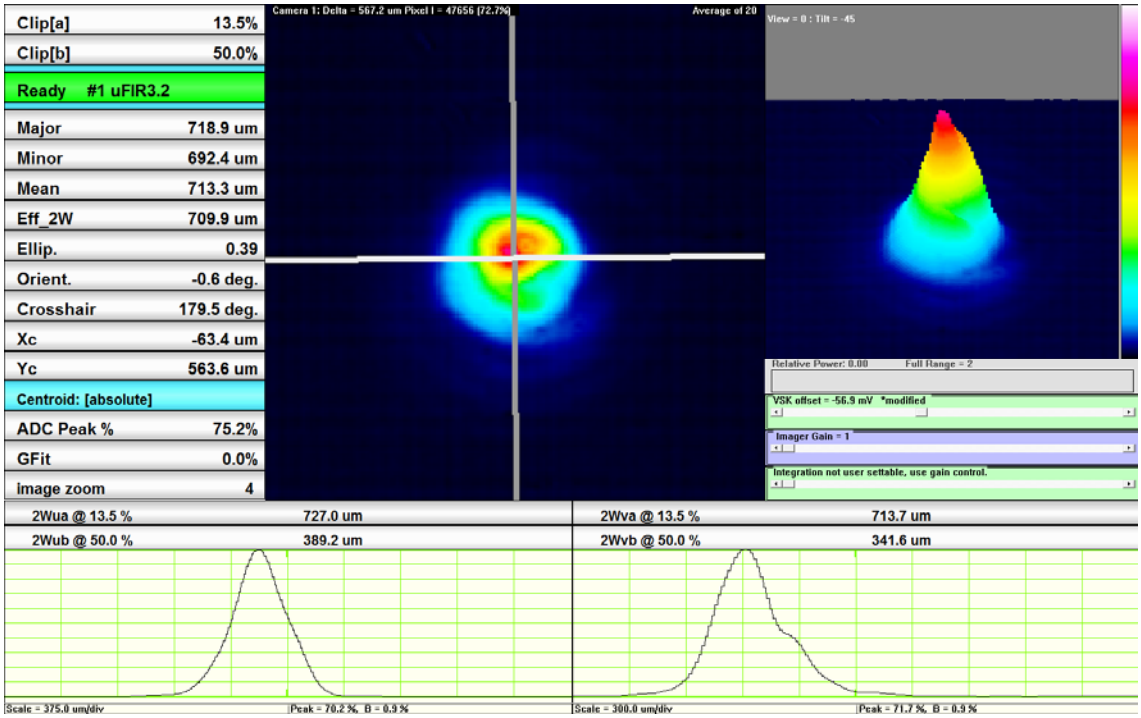
Want mainly to smooth the beam? Use **Area filter #** ≥ (Beam diameter in mm) x 2

Want to see detail in the beam? Use **Area filter #** ≤ (Beam diameter in mm) / 2

Want to compromise? Use **Area filter #** ≈ (Beam diameter in mm)

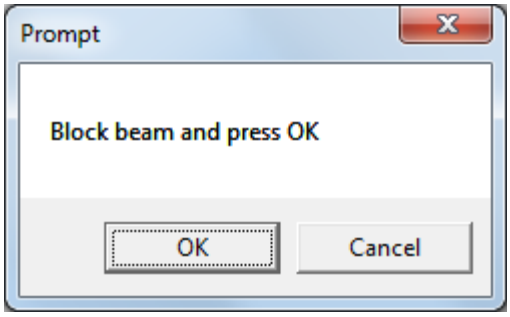
Small beam? Use **Area filter 1** & (separately) hover over the 2D area & the profiles and zoom in using the **i** button on the keyboard. (**o** to zoom out).

24) When you have set **Imager Gain**, irradiance and the options above appropriately you will arrive at something like this:



25) Optionally, in the **Average** pull-down menu set, e.g., **Average 20**.

26) **Background Subtraction** may be implemented as described in the main User Manual. Remember that after blocking the beam you must allow the software to count back up to the chosen **Average #** before pressing **OK**.



27) **Normalize**. [Not working on release 7.1H24K. to be corrected in a future release.]Optionally, press the normalize button on the toolbar to get this [This can *only* be done before saving the file; it cannot be done on a previously saved file.].

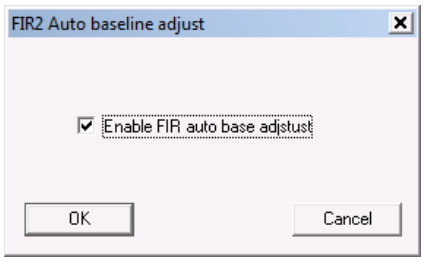
28) Press **S**top, , and block the beam to reduce the possibility of burn-in.

29) Go **File**, **Save**, **Save current data as wcf**.

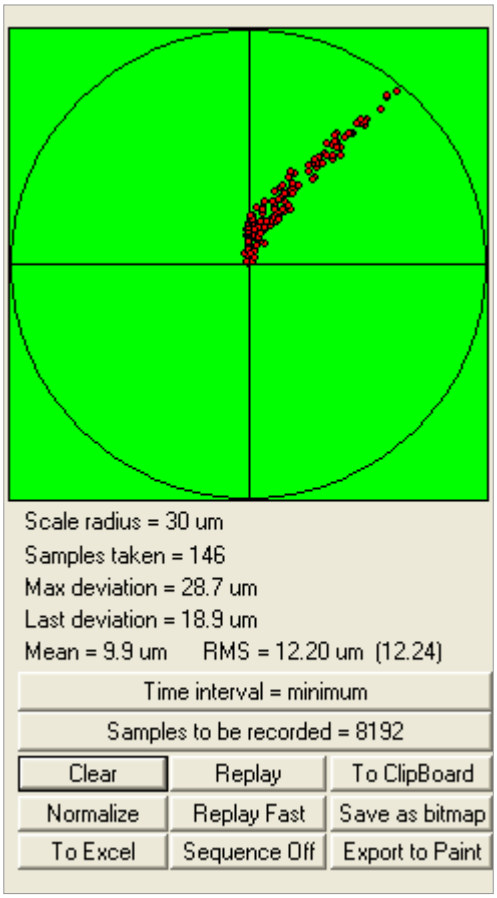
30) See or suspect a problem? Send both files to support@dataray.com. Follow up with a call to (303) 543-8235.

31) **Histogram**: By default this is not visible, and may confuse more than it helps. This shows the 0 to 100 % distribution of ADC pixel levels in the current screen. These levels are used by the **VSK** in **Auto** mode to fine adjust the VSK. To see the histogram, right–click on the 2D image and select **Show ADC Histogram (live only)**.

32) **VSK Auto baseline adjust**: [Right-click on the words **VSK offset** bar enable it, the box right. *No useful function in Ver. 7.1H24K*]

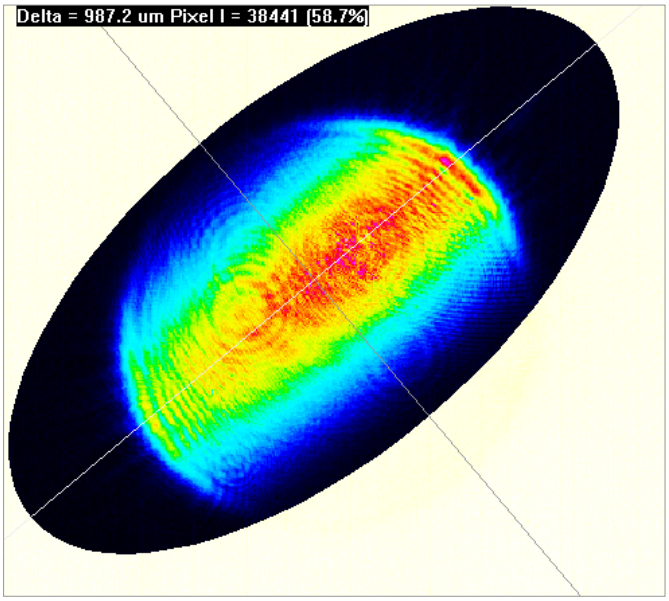


Powerful Beam Analysis Software

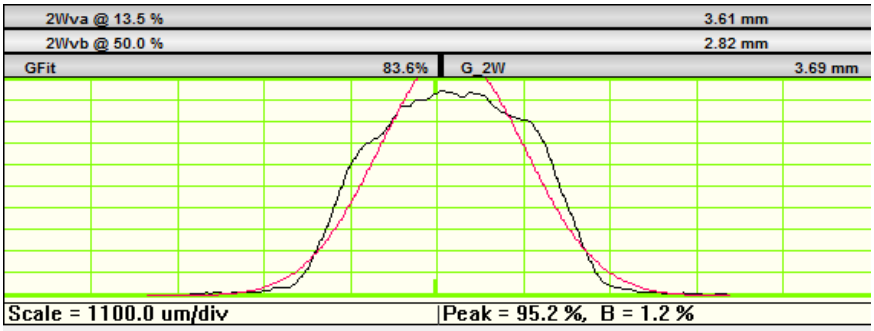


Beam Wander on a drifting Laser
Up to 8192 samples at a User Set interval.
Mean, RMS and Max. deviation.
Replay Fast or Slow.
Export to Excel, Paint, Bitmap or Clipboard.

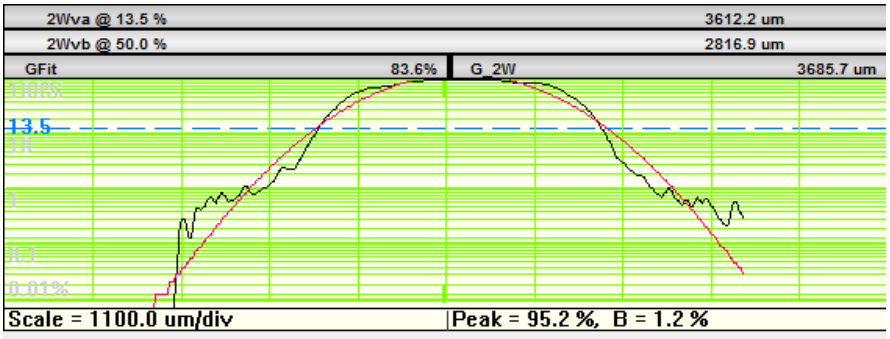
Auto-Inclusion Region on an Elliptical Beam
Automatically isolates the appropriate analysis region.
With user overrides.



Standard Linear Profile
with Gaussian Fit.



Logarithmic Profile
The same profile with Averaging & Log 40 dB display reveals structure in the wings of the beam at levels below 1%.



DataRay Innovation - The company that brought you the *first* Windows-based CCD beam profiler, the *first* thin camera for confined spaces, the *first* software slider exposure and electronic auto-shutter, the *first* standard window-free CCD for no fringing, the *first* auto-orientation on the ellipse & the *first* USB 2.0 beam profiling camera has done it again …

Compact, Room Temperature, Port Powered WinCamD-FIR cameras.

Features:

- ◊ Digital serial link for EMI immunity
- ◊ XY profiles and centroids
- ◊ Linear and logarithmic displays
- ◊ Gaussian and Top Hat least squares fits
- ◊ Ellipse Angle, Major, Minor, Mean Diameters
- ◊ Background capture and subtraction
- ◊ Image & Intensity Zoom
- ◊ Linear and area filters
- ◊ Image Averaging, 1 to continuous
- ◊ PC Or Mac-Intel Operation

WinCamD-FIR Specifications: [Preliminary specifications- subject to change without notice]

Wavelength Ranges	~2-16 µm .
Interface	USB 2.0 for laptops & desktops. 3 m standard thin cable, 5 m option.
Certification	RoHS, WEEE, CE
Measurable Sources	CW beams. Pulsed sources: *free-running, not triggerable*; average pulses over the ≈ 20 ms exposure period or with frame averaging. Mean irradiance limits still apply.
Measured Beam Powers	*See Graph above.*
Manual Beam Attenuation:	See Appendix A.
Measurement Accuracy	5 µm processing resolution for interpolated diameters. Absolute accuracy is beam profile dependent – ~35 µm accuracy is frequently achievable. Centroid accuracy is also beam dependent. It can be as good as ±20 µm since it is arithmetically derived from all pixels above the centroid clip level.
Measured & Displayed Profile Parameters	Beam Diameter: Diameter at two user set Clip levels Gaussian & Second Moment beam diameters Equivalent diameter above a user defined Clip level Equivalent Slit and Knife Edge diameters Beam Fit: Gaussian & Top Hat profile fit & % fit Equivalent Slit profile Ellipticity: Major, Minor & Mean diameters. Auto-orientation of axes. Centroid Position: Relative and absolute Intensity Weighted Centroid and Geometric Center Beam Wander Display and Statistics Smoothing Filter: Triangular running average up to 10% FWHM
Displayed Profiles Displayed Plots	2-D & 3-D plots 10, 16, 256 or max. colors or gray. Contoured display at 10 and 16 color. X-Y Profiles, 2D, 3D Plots. Zoom to x10
Processing Options	Image & profile averaging, 1, 5, 10, 20, Continuous Background Capture and Subtraction ***.job** files save all WinCamD custom settings for particular test configurations
Pass/**Fail** display Averaging Log data	On-screen, in selectable **Pass**/**Fail** colors. Ideal for QA & Production. Beam dimension running average up to 50 samples Up to 4096 samples. Centroid Min., Max., Mean, Standard Deviation.
Relative Power Measurement Fluence	Rolling histogram based on user's initial input. Units of **mW**, **µJ**, **dBm**, **%** or user choice (relative to a reference measurement input) Fluence, within user defined area
Weights: Camera Head Optional f/1, 35 mm lens	320 gm (11 oz) 320 gm (11 oz)
Minimum PC Requirements:	2 GHz Intel dual-core or higher running Windows 7/Vista/XP (32 or 64 bit); 2 GB RAM; 1 GB Hard Drive space; 1024 x 768 monitor, USB 2.0 hi-power (500 mA) port.

ORDERING INFORMATION

◊ **Limited 1 Year Warranty (excludes sensor damage)** ◊ **Free Software Upgrades** ◊ **30 Day Sale or Return Evaluation PO**

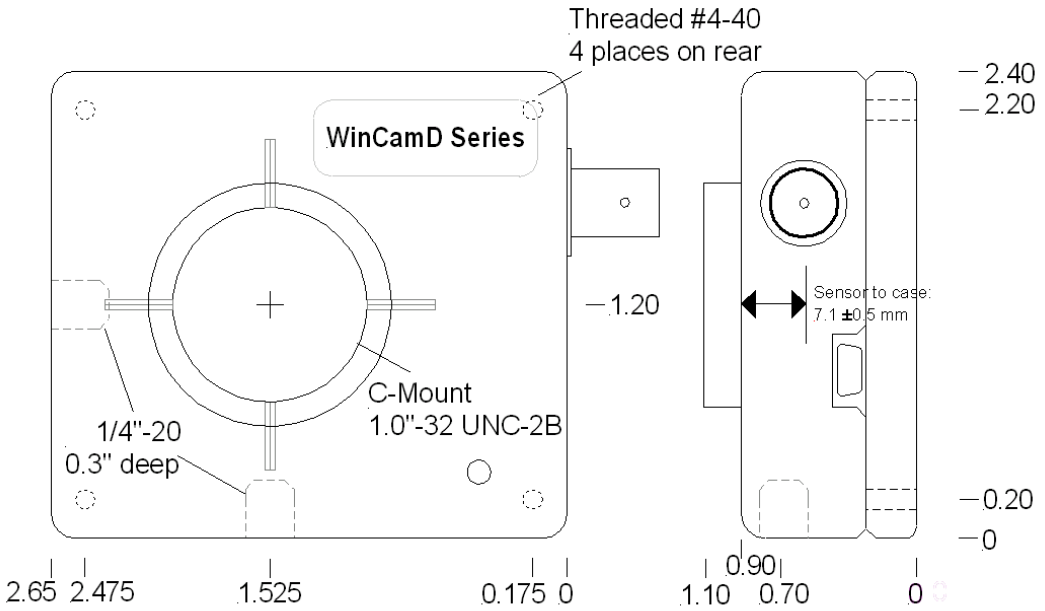
A Complete System comprises: Camera, Software, 3 m (10 ft) Cable, User Manual.

Part Number component descriptions

WinCamD-FIR2-16-HR	Complete working USB 2.0 camera system includes manual, cables, and software. 2-16 µm

Other DataRay Profiling USB 2.0 Instruments, 190 nm to 3.5 µm options.

BeamMap2	Real Time M-Squared Multi-plane profiler 0.1 micron resolution on CW lasers Centroid, Alignment, Divergence, M^2, Visible and Telecom wavelengths. *Optional* Dual Detectors 190-1800 nm
Beam'R2	0.1micron resolution on CW lasers, 0.5 micron to 4 mm beam dimensions *Optional* Dual Detectors 190-1800 nm
BeamScope-P8	100 microns to 23 mm, M^2 accessory, ISO 11146 Standard Linear scanning slit ,CW or Pulsed (PRR >5 kHz) lasers, up to 23 x 45 mm scanned area
WinCamD-UCD12	14 Bit ADC with high resolution ½" CCD array 4.65 x 4.65 µm pixels
WinCamD-UCD15	14 Bit ADC with high resolution CCD array 4.4 x 4.4 µm pixels
WinCamD-UCD23	14 Bit ADC with high resolution 2/3" CCD array 6.45 x 6.45 µm pixels
DualCamD	Measure real-time divergence and ratios with cameras at 90°
BladeCam	0.65" thin CMOS camera with ½" CMOS sensor, 5.2 x 5.2 µm pixels



WinCamD-FIR2-16-HR Outline & Mounting – Shown actual size

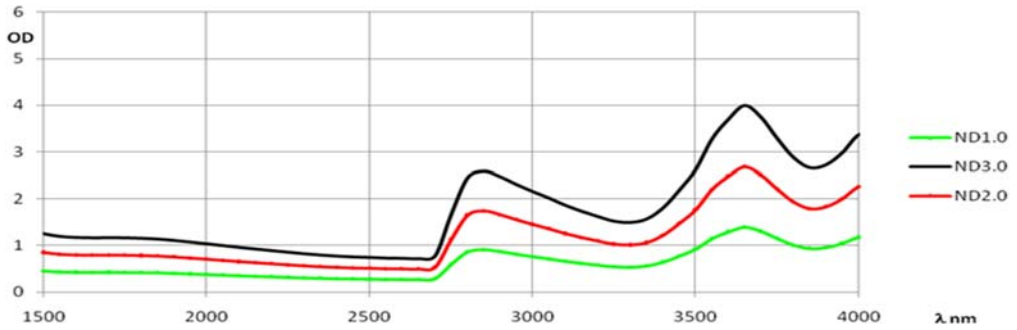
Appendix A – a non-exhaustive list of related products.

1) Power Meters for µW to W

a. Gentec-eo **XLP12-1S-H2-DO** with **P-Link** USB interface, µW to 3 W.

2) Samplers & Attenuators

a. **C-mount Absorbing Glass ND filters** mounted at 3°, originally specified for 350 to 1150 nm silicon CCD systems. The graph below shows the calculated IR transmission for these filters. Stocked by DataRay as: **ND1.0**, **ND2.0** and **ND3.0**. An **ND2.0** is provided with every system.
Damage threshold: 1 W/cm^2.

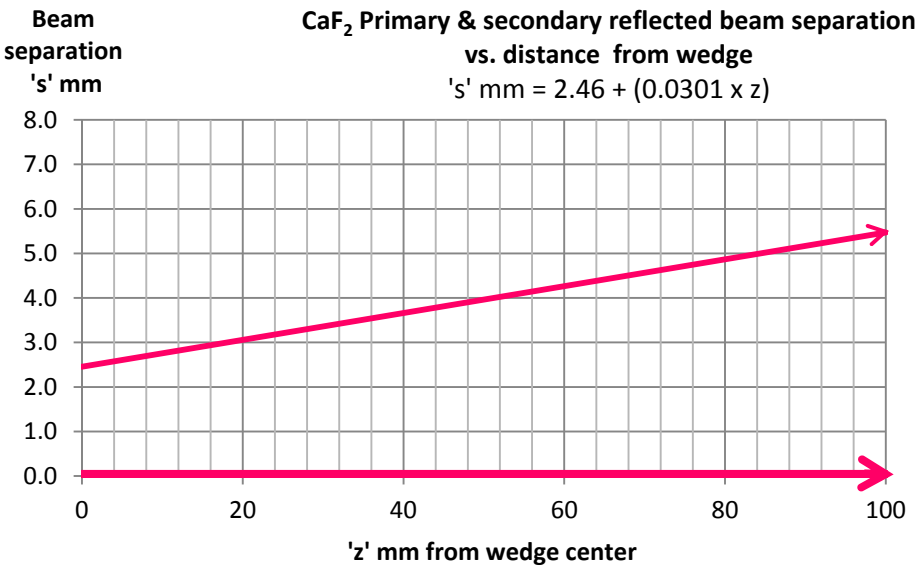


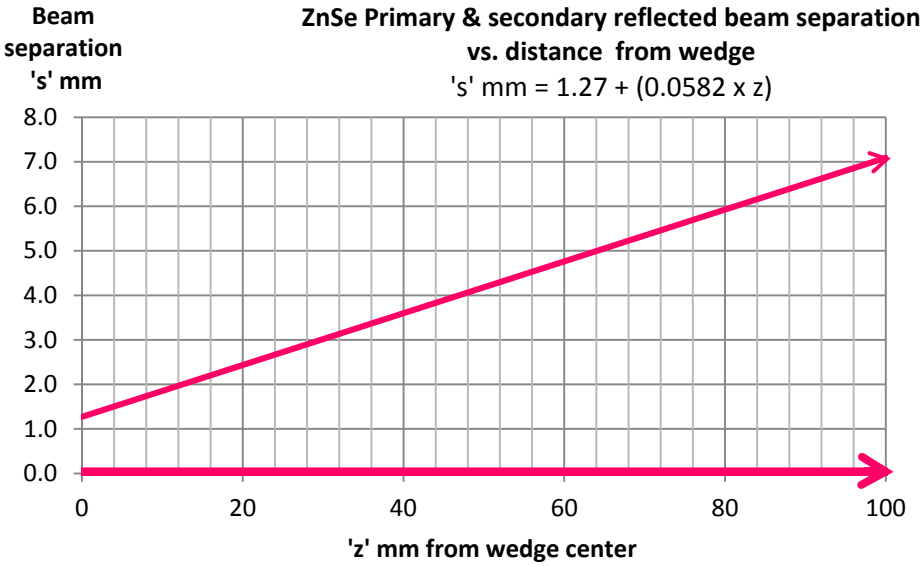
b. **C-mount IR metallic ND filters on a Ge substrate**, flat over 2-14 µm, ND 0.3, 0.5, 1.0, 2.0, 3.0. Stocked by DataRay as: **FIR-ND0.3**, **FIR-ND0.5**, **FIR-ND1.0**, **FIR-ND2.0** & **FIR-ND3.0**.
Damage threshold: TBA W/cm^2. *May give fringing due to plane parallel internal reflection.*

c. **ZnSe FIR Wire Grid Polarizer**. Extinction Ratio: 100 at 3 µm, 300 at 10.6 µm. Available in a C-mount rotating mount as: **FIR-WGP-RM**
Damage threshold: 50 W/cm^2; 2J/cm^2 @ 100ns

d. **Wedge beamsplitters**. ZnSe 3° and CaF_2 unmounted 25 mm diameter wedge beamsplitters. Stocked by DataRay as: **FIR-W-CAF2-3**, **FIR-W-ZnSe-3** for unmounted wedges, or **FIR-MW-CAF2-3**, **FIR-MW-ZnSe-3** for a mounted wedge.
Damage threshold: 50 W/cm^2; 5 J/cm^2 at 10.6 µm, 100 ns, 1 Hz

	Reflectivity at 45°				Two orthogonal wedges	
	s %	p %	Ratio	Av. %	%	Ratio
CaF_2	6.85	0.47	14.6:1	3.66	0.032	3115:1
ZnSe	27.9	9.8	3.58:1	17.1	2.18	46:1





e. AR coated wedges. 0.5% reflectivity. TBA.

f. C-mount OD 0.30 & 0.76 25.4 mm diameter CaF_2 10.6 µm attenuators.
Stocked by DataRay as: **FIR-CaF2-0D0.3**, **FIR-CaF2-0D0.76**
Damage threshold: 50 W/cm^2; 5 J/cm^2 at 10.6 µm, 100 ns, 1 Hz

Appendix B – Defective Pixels Specification

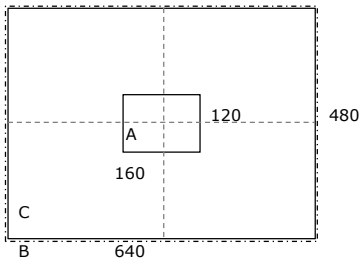
A pixel is considered non-operating if:

- It's responsivity is <0.8 x or >1.2 x average responsivity
- It's NETD is >1.5 x average NETD defined in the related document

A single non-operating pixel is a non-operating pixel with no adjacent non-operating pixel.

Area: THE FPA is divided into three areas which have the same optical axis:

- Area A: the central zone of 160 x 120 pixels
- Area B: the peripheral 3 lines and columns
- Area C: the 640 x 480 area (i.e. excluding areas A and B) of the array.



Cluster: A cluster is defined as a group of at least two non-operating pixels adjacent by side or corner. Clusters are defined by their size in terms of non-operating pixels. E.g. 'Cluster 3' is 3 adjacent pixels.

Non-operating row: A row is considered non-operating if more than 50% of the pixels in this row are non-operating.

Non-operating column: A column is considered non-operating if more than 50% of the pixels in this column are no-operating.

Operability Specification

	Area A	Area B	Area C
Operability	>99.5%	NA	>99.5%
Cluster 3	4	12	12
Cluster 4	2	7	7
Cluster 5	0	5	5
Cluster 6	0	3	3
Cluster 7	0	2	2
Cluster 8	0	2	2
Cluster 9	0	1	1
Cluster 10			
Cluster 11			
Cluster 12			
Cluster 13			
Cluster 14			
Line	0	1	0
Column	0	1	0